

The Ecology and Local Distribution of Non-marine Aquatic Gastropods in Viti Levu, Fiji

by

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Abstract. Freshwater habitats throughout the island of Viti Levu, Fiji were investigated for gastropods, water conductivity, water hardness, temperature, substrate, and current speed from August 1982 to February 1984. In general the values of conductivity, hardness, and temperature increased toward the sea; but this was not true of all river systems and these factors were not as important in influencing the distribution of the 32 gastropod species as were physical factors, specifically distance from the sea, substrate, and current speed. Using these physical factors the running water gastropods were classified into five groups. Gastropods were absent from long stretches of all rivers where the water was deep and turbid and the bottom unstable.

INTRODUCTION

DURING 1971 STARMÜHLNER (1976) sampled the gastropods at stations near the town of Suva and near the forestry station of Nadarivatu on the island of Viti Levu, Fiji. However, no further sampling of gastropods in the remaining extensive network of rivers and streams on Viti Levu has been reported.

The aim of this study was to find the distribution of the freshwater gastropods on the island of Viti Levu, Fiji and to establish the factors that were most important in influencing the distribution of the various species.

STUDY AREA

Viti Levu is an oval-shaped island, reaching about 150 km long and 100 km wide (Figure 1). The interior is mountainous and the highest peak, Mt. Victoria (Tomaniivi), is 1312 m high. Because Viti Levu is in the path of the southeast trade winds, the southeastern side and the interior receive heavy rainfall and are covered in rain forest, while the northwestern side is comparatively dry and much of it is used for growing sugar cane. The mean annual temperature is 29–30°C and the annual rainfall is about 3000 mm.

The two longest rivers are the Rewa and Sigatoka, which rise in the central high country and flow southward. The Rewa River system drains nearly one-third of the island. Recently two artificial lakes have been formed. The construction of a hydroelectric dam on the upper Rewa River

resulted in Lake Monasavu, and a dam to impound water to supply the towns of Lautoka and Nadi has produced Lake Vaturu (Figure 1).

MATERIALS AND METHODS

Gastropods were collected from rivers, streams, and lakes from July 1982 to February 1984. The collecting stations 1–47 are shown on the map of Viti Levu (Figure 1). They were chosen to be as representative as possible while being accessible by road or track.

The river bed and plants at each station were searched for 30 min. The upper and lower surfaces of stones and boulders were searched, leaf litter and water-weed were inspected, and sand and gravel were sieved. Representatives of all gastropod species were collected and taken to the laboratory for identification. Shell, operculum, radula, and reproductive organs were used in the identification of the snails following several authors: MOUSSON (1870), RIECH (1937), BENTHEM-JUTTING (1956), FRANC (1956), STARMÜHLNER (1970, 1976).

Water speed was estimated by timing a float between two fixed points, the water temperature was taken to the nearest 0.5°C, and in some cases a water sample was collected from the station. At the Institute of Natural Resources, University of the South Pacific, water samples were analyzed for conductivity (μs), which indicates the total ion concentration, and for hardness ($\text{mg CaCO}_3/\text{L}$) by titration with EDTA (ethylene-diaminetetraacetic acid).

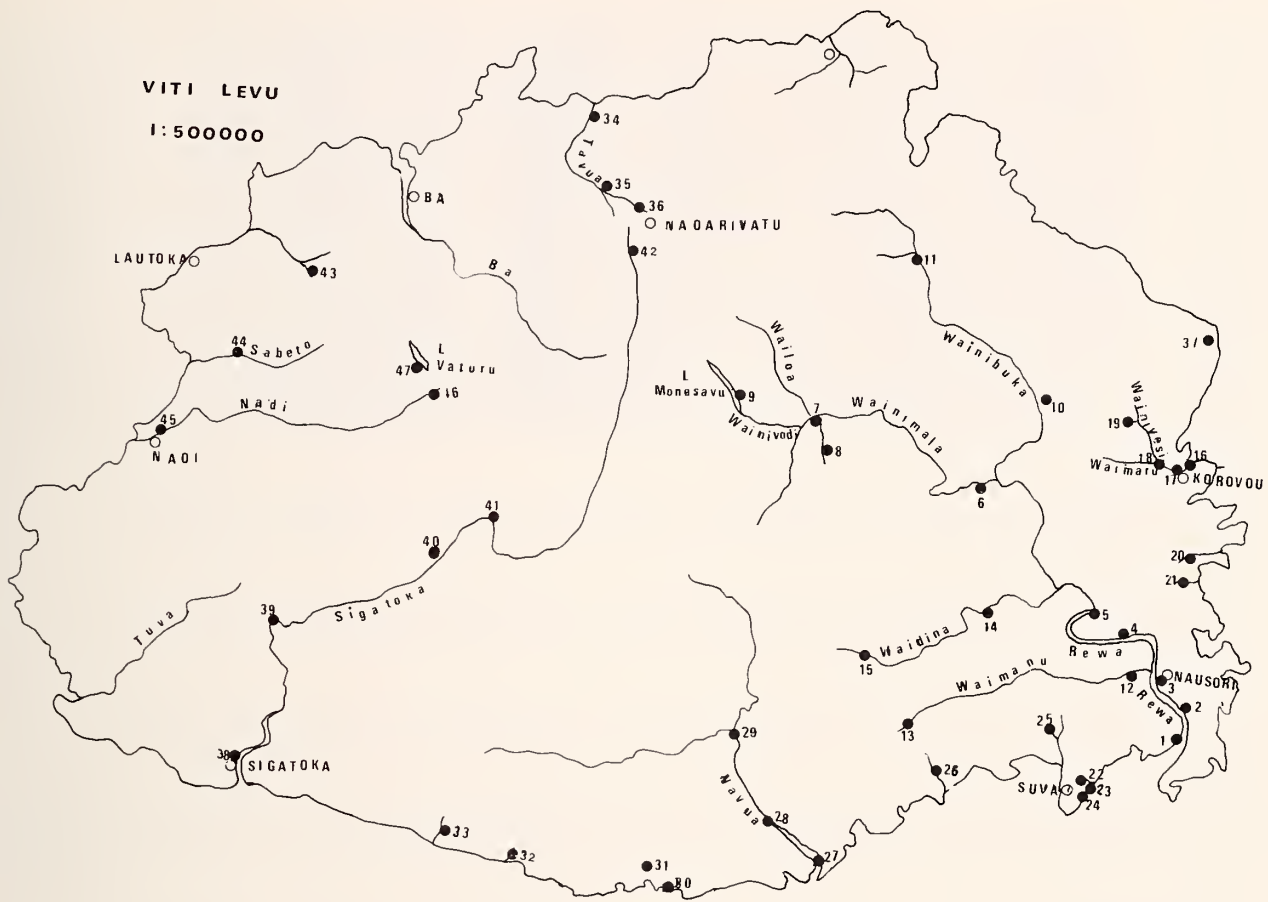


Figure 1

A map of the main river systems of Viti Levu, Fiji showing the localities of sampling stations 1–47.

RESULTS

Species Found

Thirty-two species were found and identified (Table 1). The nomenclature of STARMÜHLNER (1976) has been used where possible.

The gastropods found in still water were the pulmonates *Planorbarius corneus* (Linnaeus, 1758), *Physastra nasuta* (Morelet, 1856), *Ferrissia noumeensis* (Crosse, 1871), *Gyraulus montrouzieri* (Gassies, 1863), and the prosobranch *Melanoides tuberculata* (O. F. Müller, 1774). The European snail *Planorbarius corneus* was probably introduced into station 24 from a freshwater aquarium. *Melanoides tuberculata* was the most widespread species; it was found at 22 of the 47 stations. *Physastra nasuta* was the next most widespread species, being found at 14 stations. Both species lived in ditches and dalo patches on gravel and mud as well as on stones in water currents as fast as 80 cm/s (Table 1). *Ferrissia noumeensis* was present on stones, gravel, and water plants at seven stations—two ponds, two small streams (stations 21, 23), one slowly

flowing river (station 17), and two fast flowing inland rivers (stations 11, 19). This suggests that it is also widespread but often overlooked because of its small size (<5.0 mm). *Gyraulus montrouzieri* was found on water-weed in still and slowly flowing water at two stations (23, 30).

The remaining gastropod species lived in running water. Using the parameters of distance from the sea, current speed, and bottom substrate of the river or stream in which they lived, these gastropods can be divided into 5 groups:

- (1) 200 m–2 km from the sea in currents from 0 to 10 cm/s, substrate of mud or sand with some rocks and water plants: *Assiminea crosseana* (Gassies, 1858) on plants, *Clithon oualaniensis* (Lesson, 1831) on sand or mud, *Neritina turrata* (Gmelin, 1790) on mud, *Clithon spinosus* (Budgin, 1845), and *Neritina auriculata* Lamarck, 1816, on rocks.
- (2) 300 m–8 km from the sea in a current up to 40 cm/s, substrate of stones and rocks: *Clithon corona* (Linné, 1758), *Clithon diadema souleyetana* (Récluz, 1841), and *Melanoides arthurii* (Brot, 1871).

Table 1
The physical conditions, results of water analysis, and gastropods present at the sampling stations. ND = not determined.

Sam- pling station number	River & map reference (1:50,000 Viti Levu)	Substrate	Distance from sea (km)	Water speed (cm/s)	Temper- ature (°C)	Total ion concentra- tion (µs)	Hardness (mg CaCO ₃ /L)	Gastropods present
1	Rewa R. (tidal), Lokia landing, XE644983	sand, rocks & plants	2	0-10	25	190	78	<i>Neritina turtoni</i> , <i>N. squamipicta</i> , <i>Septaria porcellana depressa</i> , <i>Thiara bellicosa</i> , <i>Assiminea crosseana</i>
2	Rewa R. (tidal), Nausori airport, XF622060	mud	8	0-10	26	111.6	51	<i>Neritina turtoni</i> , <i>N. squamipicta</i> , <i>Thiara belliosa</i> , <i>Clithon corona</i>
3	Rewa R., Nausori bridge, XF651041	mud, sand & plants	11	0-10	27	99	43	<i>Neritina turtoni</i> , <i>N. squamipicta</i> , <i>Septaria li-neata</i> , <i>Melanooides aspirans</i>
4	Rewa R., XF552110	mud, weed & wood	22	0-10	27	ND	ND	<i>Neritina turtoni</i> , <i>N. squamipicta</i>
5	Rewa R. at Baulevu, XF530135	mud & shingle	38	0-10	26.5	98.6	39	(<i>Batissa violacea</i> , a freshwater clam)
6	Waimimala R. at Serca, XF380265	shingle	72	30-50	26.5	50.3	25.5	—
7	Waimimala R., 2 km below Lasele- vu, XF202367	shingle & boul- ders	90	30-40	24	82.2	31	<i>Fijidoma maculata</i> , <i>Physastra nasuta</i>
8	Stream into Waimimala R., 1.5 km above Matainisau, XF190339	shingle & boul- ders	97	40-60	23	75.5	35	<i>Fijidoma maculata</i> , <i>Fluviopupa pupoidea</i> , <i>Melanooides tuberculata</i> , <i>Physastra nasuta</i>
9	Lake Monasavu, XF115377	mud & stones	110	0	25	ND	ND	<i>Physastra nasuta</i>
10	Stream into Wainibuka R., 1 km south Wailotau, XF340479	boulders	77	0-60	25	68.5	28	<i>Melanooides tuberculata</i> , <i>Septaria porcellana de-pressa</i>
11	Wainibuka R., 1.8 km south of Ro- kovuaka, XF340479	stones & boulders	100	50-80	29	132.8	66	<i>Fijidoma maculata</i> , <i>Fluviopupa pupoidea</i> , <i>Melanooides tuberculata</i> , <i>Physastra nasuta</i> , <i>Thiara scabra</i> , <i>Ferrissia noumeensis</i>
12	Waimanu R. pumphouse, XE552059	stones	21	20-30	25	80	35	—
13	Stream into Waimanu R., Namosi road, XE274997	stones & boulders	46	30-50	23	73.7	34	<i>Melanooides tuberculata</i>
14	Waidina R., Monasavu road, XF470155	stones	43	30-50	23	42.6	19.5	<i>Physastra nasuta</i>
15	Waidina R. at Namosi, XF212055	stones & boulders	82	0-30	23.5	63.2	31	<i>Fluviopupa pupoidea</i> , <i>Melanooides lutosa</i> , <i>M. tuberculata</i>
16	Waimara R. at end of road, XF668315	mud, sand & stones	2	0	28	131.4	55	<i>Clithon diadema souleyetana</i> , <i>Neritina auriculata</i>
17	Waimara R. at Korovou, XF630325	mud & water- weed	5	0-10	28.5	91.3	38.8	<i>Ferrissia noumeensis</i> , <i>Neritilia rubida</i>
18	Junction of Wainivesi & Waimara Rs., XF630325	gravel & stones	10	20-30	29.5	99	44.9	<i>Melanooides tuberculata</i>
19	Stream into Wainivesi R., XF595375	gravel, stones & boulders	15	0-30	28	89.5	39.1	<i>Ferrissia noumeensis</i> , <i>Fluviopupa pupoidea</i> , <i>Melanooides lutosa</i> , <i>M. tuberculata</i> , <i>Physastra nasuta</i> , <i>Neritina pulligera</i>

Table 1
Continued.

Sam- pling station number	River & map reference (1:50,000 Viti Levu)	Substrate	Distance from sea (km)	Water speed (cm/s)	Temper- ature (°C)	Total ion concentra- tion (μ s)	Hardness (mg CaCO ₃ /L)	Gastropods present
20	Waidalice R. at end of road, XF645250	mud & stones	5	0-10	29	ND	ND	<i>Clithon corona</i> , <i>Neritina squamipicta</i> , <i>Septaria lineata</i>
21	Stream at forestry, XF635170	rock & weed	4	0-20	30	ND	ND	<i>Ferrissia noumeensis</i> , <i>Melanooides tuberculata</i>
22	Uluituni Cr., mangroves, Suva, XE534926	mud & leaves	0.2	0	29	ND	ND	<i>Clithon oualianensis</i> , <i>Neritina auriculata</i> , <i>N. turrita</i> (marine: <i>Melampus striatus</i> , <i>Pythia scarabaeus</i> , <i>Littorina undulata</i>)
23	Uluituni Cr., USP campus, stream, XE532928	mud, gravel & weed	0.3	10	29	ND	ND	<i>Ferrissia noumeensis</i> , <i>Gyraulus montrouzieri</i> , <i>Melanooides tuberculata</i> , <i>M. arthurii</i> , <i>Physastra nasuta</i>
24	Lily pond, Suva Grammar School, XE532922	mud & plants	0.3	0	28	ND	ND	<i>Ferrissia noumeensis</i> , <i>Melanooides tuberculata</i> , <i>Physastra nasuta</i> , <i>Planorbis corneus</i>
25	Vago Cr., Wailuku, XF529007	shingles, boulders & rocks	5	40-80	24	62.8	31	<i>Melanooides tuberculata</i> , <i>M. aspirans</i> , <i>Neritina pulligera</i> , <i>N. petiti</i> , <i>N. macgillivrayi</i> , <i>Septaria suffreni</i> , <i>S. porcellana depressa</i> , <i>Thiara terpsichore</i> , <i>T. amarula</i>
26	Creek beside Nabukavesi-Namosi road, XE312925	gravel & shingle	4	30-40	26	49.6	19.5	<i>Melanooides arthurii</i> , <i>M. tuberculata</i>
27	Navua R. at bridge, XE224856	mud, rocks & plants	4	0-10	25	68.8	33	<i>Neritina rubida</i> , <i>N. squamipicta</i> , <i>N. turtoni</i>
28	Navua R. at Waiyanitu, XE185888	gravel & stones	15	30	25	68.5	34.5	—
29	Navua R. at Namuamua, XE129990	shingle & boul- ders	28	30-50	25	ND	ND	<i>Neritina pulligera</i>
30	Lily ponds, Pacific Harbour, XE138819	mud & plants	0.3	0	28	ND	ND	<i>Ferrissia noumeensis</i> , <i>Gyraulus montrouzieri</i> , <i>Melanooides tuberculata</i>
31	Sago swamp, Pacific Harbour, XE134847	mud & dead leaves	2	0	28	ND	ND	<i>Melanooides tuberculata</i> , <i>Physastra nasuta</i>
32	Stream on Coral coast, WE825855	sand, gravel & boulders	0.3	10-30	29	ND	ND	<i>Clithon corona</i> , <i>Neritina petiti</i> , <i>Melanooides tuberculata</i>
33	Korolevu Cr., upstream from air- strip, WE780878	stones	2	30-40	28	ND	ND	<i>Neritina pulligera</i> , <i>Septaria porcellana depressa</i>
34	Tavua R. town bridge, WF925720	mud & stones	2	0-10	30	601	237.9	<i>Clithon diadema souleyetana</i> , <i>Neritina turtoni</i> , <i>N. squamipicta</i> , <i>Septaria porcellana depressa</i>
35	Waikubakuba R. at village, WF988920	shingle & boul- ders	14	40-60	25	135.2	64.2	<i>Melanooides tuberculata</i> , <i>Physastra nasuta</i>
36	Stream into Waikubakuba R. at Nadarivatu, XF029579	boulders	18	0-50	22	55.1	26.6	<i>Fluviopupa pupoidea</i>

Table 1
Continued.

Sam- pling station number	River & map reference (1:50,000 Viti Levu)	Substrate	Distance from sea (km)	Water speed (cm/s)	Temp- erature (°C)	Total ion concentra- tion (μ s)	Hardness (mg CaCO ₃ /L)	Gastropods present
37	Stream between Lodoni & Natovi, XF676440	stones	0.5	20-40	27	ND	ND	<i>Cithon diadema souleyetana</i> , <i>C. corona</i> , <i>Melano- ides aspirans</i> , <i>Septaria porcellana depres- sa</i>
38	Sigatoka R. at town bridge, WE545948	mud, wood & stones	2	0-10	28	164	91	<i>Cithon spinosa</i> , <i>Neritina turtoni</i> , <i>N. auricula- ta</i> , <i>N. turrita</i> , <i>Septaria luzonica</i>
39	Sigatoka R., 20 km upstream from bridge, WF635130	stones	22	30-50	28	151.9	103	—
40	Stream into Sigatoka R., near Tuvu, WF790214	gravel, stones & rocks	50	0-60	26.5	267	131	<i>Melanoides tuberculata</i> , <i>Thiara scabra</i>
41	Sigatoka R., 2 km upstream from Ketyasi, WF835230	stones	65	50-60	26.0	161.7	71	<i>Fluviopupa pupoidea</i> , <i>Melanoides tuberculata</i>
42	Nadala Cr. into Sigatoka R. at Na- darivatu, XF023566	shingle & boul- ders	110	20-40	23	43.1	21.2	<i>Melanoides lutosus</i> , <i>M. tuberculata</i> , <i>Physastra nasuta</i>
43	Stream at Vakabuli, WF595525	stones	8	20-40	28	ND	ND	<i>Melanoides aspirans</i> , <i>M. tuberculata</i> , <i>Physastra nasuta</i> , <i>Septaria suffreni</i>
44	Sabeto R., near power station, WF525410	stones & rocks	6	50-80	27	ND	ND	<i>Melanoides tuberculata</i> , <i>Neritina pulligera</i> , <i>Septaria porcellana depressa</i> , <i>S. suffreni</i>
45	Nadi R. at town bridge, WF445322	mud & stones	4	0-10	32	229	90	<i>Cithon diadema souleyetana</i> , <i>Melanoides pli- caria</i> , <i>Neritina squampicia</i> , <i>Septaria luzoni- ca</i> , <i>S. porcellana depressa</i> , <i>Thiara terp- sichore</i>
46	Nadi R. at Natawa, WF711349	gravel, stones & boulders	35	30-60	25	231	99	<i>Fluviopupa pupoidea</i> , <i>Melanoides lutosus</i> , <i>M. tuberculata</i> , <i>Physastra nasuta</i>
47	Lake Vaturu, WF705375	mud & stones	38	0	28	53.5	32	<i>Melanoides tuberculata</i> , <i>Physastra nasuta</i>

- (3) 2–11 km from the sea in currents from 0 to 10 cm/s, substrate of mud and sand with some rocks and water plants: *Melanooides plicaria* (Born, 1780) on mud and sand, *Neritilia rubida* (Pease, 1867) on plants, *Septaria lineata* (Lamarck, 1816) and *Neritina squamipicta* Récluz, 1843, on plants and rocks, *Neritina turtoni* (Récluz, 1843) on mud and rocks, and *Thiara bellicosa* (Hinds, 1844) on mud. *Neritina squamipicta* and *N. turtoni* were found 22 km from the sea (station 4).
- (4) 300 m–11 km from the sea in currents from 20 to 80 cm/s, substrate of rocks and boulders with patches of stones and gravel: *Melanooides aspirans* (Hinds, 1847), *Thiara amarula* (Linné, 1758), and *Thiara terpsichore* (Gould, 1847) on gravel and stones in slower currents, and *Neritina macgillivrayi* (Reeve, 1855), *Neritina petiti* Récluz, 1843, *Neritina pulligera* (Linné, 1767), *Septaria porcellana depressa* (Linné, 1758), and *Septaria suffreni* (Récluz, 1841) on rocks. *Septaria porcellana depressa* was found 77 km (station 10) and *N. pulligera* 28 km (station 29) from the sea.
- (5) 15–110 km from the sea in currents from 30 to 80 cm/s, substrate of stones, boulders, and rocks: *Fijidoma maculata* (Mousson, 1865) on stones, *Fluviopupa pupoidea* Pilsbry, 1911, *Melanooides lutosa* (Gould, 1847), and *Thiara scabra* (O. F. Müller, 1774) on stones, boulders, and rocks (Table 1).

Characteristics of the River Systems

When the physical data from all the river systems were pooled, an inverse correlation was found between distance from the sea and temperature ($P < 0.05$), hardness ($P < 0.05$), and total ions ($P < 0.01$) (Spearman's rank correlation coefficient r_s , ELLIOTT, 1977). Generally, however, the number of gastropod species did not follow this inverse correlation. More often there were more species near the mouth of the rivers and in the headwaters than in the middle reaches.

The pattern of decreasing temperature, total ions, and hardness with increasing distance from the sea was not apparent in all rivers. However, this was the trend in the short, steep Waikubakuba-Tavua river system (Figure 1, stations 34, 35, 36) where temperature (30, 25, 22°C), total ions (601, 135.2, 55.1 μs), and hardness (237.9, 66.2, 26.6 mg CaCO_3/L) decreased as distance (2, 14, 36 km) increased.

The lowland Wainivesi-Waimara system illustrated the lack of correlation between distance from the sea and the number of species found. Here, there were two gastropod species 2 km from the mouth, two other species 5 km from the sea at station 17, one species 10 km inland at station 18, and six species in the headwaters at station 19 (Figure 1). In this river system there was little variation in water hardness (55, 38.8, 44.9, 39.1 mg CaCO_3/L), or temperature (28, 28.5, 29.5, 28°C) from mouth to headwater (Table 1).

All of the rivers and streams studied contained sufficient

dissolved ions to support a gastropod population. The lowest conductivity, 43.1 μs , was obtained at Nadala Creek, station 42 (Figure 1), where the three gastropods *Melanooides tuberculata*, *M. lutosa*, and *Physastra nasuta* were frequently found. The total ion concentration here was low compared with that in the water of the English Lake district where the main ions are sodium and calcium in equal proportions and the conductivity is 112 μs , or with those in a limestone stream such as the river Avon (Wiltshire, England) which has a conductivity of about 450 μs , or with those in water of salinity 3‰ which has a conductivity of 6000 μs (MACKERETH *et al.*, 1978; HAYNES, 1982).

The concentration of calcium ions necessary for the presence of mollusks varies but if the quantity of water is great enough they will tolerate low concentrations. For example, *Planorbis carinatus* is common in Lake Windermere, England where the calcium concentration is 5 mg/L (MACAN, 1974). The lowest values for hardness in this study were 21.1 mg CaCO_3/L at station 42 and 19.5 mg CaCO_3/L at station 26 (Figure 1). *Melanooides arthurii*, *M. tuberculata*, *M. lutosa*, and *Physastra nasuta* were present at one or both of these stations.

The water temperature varied from 22 to 32°C. Although generally the water was warmer nearer the river mouth, inland species such as *Fijidoma maculata* and *Fluviopupa pupoidea* were found in temperatures up to 29°C (station 11). It is possible that they were restricted to inland streams because they require a low temperature (22–23°C) for reproduction.

Gastropods were absent from long stretches of the larger rivers (stations 6, 12, 28, 22) due to unstable bottom substrates and to the depth of the often turbid water. The freshwater clam *Batissa violacea* Lamarck was often present under such conditions.

DISCUSSION

All the species found have been reported from other Pacific islands (RIECH, 1937; STARMÜHLNER, 1970, 1976). However, four species, *Gyraulus montrouzieri*, *Planorbis corneus*, *Clithon spinosus*, and *Neritina squamipicta*, have not been reported previously from Fiji. In addition, *Fijidoma maculata* has been previously recorded only from swift flowing parts of the Rewa and Lami river systems, Viti Levu (MORRISON, 1954). In this survey it was found in the headwaters of the Rewa, at stations 7 and 8 in the Wainimala River, and at station 11 in the Wainibuka River where it reached a density of 2250/m².

Decreases in total ion concentration and temperature in the mountain streams of Madagascar, Sri Lanka, and New Caledonia similar to those observed in the Waikubakuba-Tavua river system were reported by STARMÜHLNER (1979). These trends were absent in some of the longer river systems of Fiji.

When Starmühlner sampled the Vago Creek (station 25) in 1971 (STARMÜHLNER, 1976) he reported a water

speed of 0.5–1 m/s, a temperature of 23.6°C, a total ion concentration of 45 μ s, and the following species present: *Neritina pulligera*, *Septaria porcellana depressa*, *Thiara amarula*, *Melanoides aspirans* and *M. tuberculata*. This is not dissimilar to the findings of the present study when the water speed was 40–80 cm/s, the temperature 24°C, the total ion concentration 62.8 μ s, and the same species were found as in 1971 plus *Septaria suffreni*, *Thiara terpsichore*, *Neritina macgillivrayi*, and *N. petiti*. Starmühlner also sampled at Nausori (station 3) where he found the temperature was 27.4°C compared with 27°C in this study. The species that he found were *Neritina turtoni*, *Septaria lineata* and *Thiara bellicosa*. In this study *T. bellicosa* was absent but *Neritina squamipicta* and *Melanoides aspirans* were present.

Starmühlner sampled at 8 stations in the Suva area and J. A. McLean sampled at 4 stations in the interior near Nadarivatu (STARMÜHLNER, 1976). Starmühlner found 18 species, three of these were not discovered in this survey. These were *Clithon olivaceus* (Récluz), *Neritina canalis* (Sowerby), and *Septaria macrocephala* (Le Guillou). All three were found during 1983 in clear torrential streams on the relatively undeveloped Fiji islands of Ovalau, Taveuni, Kadavu, and Gau. It is possible that they have become rare on Viti Levu due to the increase in road building and logging. Both activities disturb the soil which is then washed into the rivers and streams during heavy rains and increases the turbidity of the water. Mud is deposited on rocks and stones where it inhibits the growth of algae, the main food source of these gastropods.

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